Sonar Detection and Classification of Buried or Partially Buried Objects in Cluttered Environments Using UUVs

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LONG TERM GOALS

The long term goal of this program is to develop acoustic reflection methods and signal processing techniques for detecting, imaging and classifying objects buried in or resting on the seabed such that the methods can be eventually implemented on UUVs.

OBJECTIVES

- To develop acoustic and signal processing technologies for detecting and visualizing buried objects and objects lying on the seabed
- To determine the best image processing and visualization techniques for buried object imaging
- To generate databases of buried target strengths, volume and surface scattering coefficients and sediment acoustic properties over a wide frequency range that can be used for sonar prediction modeling
- To develop sonar models that predict the SNR of targets for various array geometries, sediment types, frequency bands, etc .
- To develop acoustic models of sound interacting with the seafloor to provide a theoretical basis for signal processing techniques and predicting the detection of buried objects

APPROACH

Buried Object Detection

In order to develop a UUV sonar for detecting and imaging buried objects, the phenomenon of volume and surface scattering from the sediments, fluid / porous solid boundary-interacting acoustics, and the interaction of sound with elastic objects contained with a porous solid must be understood so that the signal levels and interference can be accurately calculated when estimating sonar performance of a particular design. A sonar system has been developed to measure those acoustic processes and to generate imagery of buried objects.

CEROS (DARPA) funded a compact version of the imaging sonar based on technology developed in this ONR program. This sonar uses a steerable transmit beam and a beamformer that provides across

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14. ABSTRACT
The long term goal of this program is to develop acoustic reflection methods and signal processing techniques for detecting, imaging and classifying objects buried in or resting on the seabed such that the methods can be eventually implemented on UUVs.

15. SUBJECT TERMS

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track and along track focusing. This sonar has a frequency range of 5-23 kHz. The 1 meter long by 1 meter wide towed vehicle contains a six element transmission array and eight line hydrophone arrays with 4 segments each. The sonar processor on the fish steers the transmission beam forward and aft to any selected angle of incidence and acquires 32 channels of reflection data which is sent to the topside processor via 100 Base T for display and storage. The sonars provides integrated video and acoustic data sets for measuring the impulse response of buried targets and the scattering interference from sediments in the vicinity of the targets. The compact sonar steers the transmission beam forward thereby substantially reducing the high scattering levels from the sediment water interface at near normal incidence that make it difficult to detect objects near the interface. Substantial testing and analysis was conducted on data collected by the buried object imaging sonar at a test range in Hawaii. Sonar performance was established and images of many types of objects buried in sand were generated including ordnance, pipes and cylinders.

Since the feasibility of finding buried objects as small as ordnance shells was firmly established using the buried object image technology developed under this ONR program, a new effort was started in FY2000 to repackage the sonars for AUV operations. The repackaged sonars will be low power (<200W) for AUV deployment and will process data within the on board sonar processor so buried targets can be detected in real time and reported via acoustic modem to the surface support ship.

Automatic Bottom Mine Detection

Mine detection of proud bottom mines can be detected using a different approach (than used for detecting buried mines) while obtaining much greater swath coverage. Proud mine create acoustic shadows which are readily detectable in sidescan imagery in practically all environments. A 850 kHz chirp sonar was designed and constructed to provide AUVs with the capability of automatically detecting mines lying on the seabed and reporting mine positions to a surface ship as the mines are detected. The operating frequency of 850 kHz was selected to ensure that the wavelength was short enough so that scattering of sloping target surfaces could be used to provide detailed target images. Automatic detection of mines is performed in real time using a 466 MHz Celeron processor and fuzzy pattern recognition procedures which analyze the acoustic shadows produced by mines resting on the seabed. The fuzzy pattern recognition procedure uses characteristics of shadows detected in acoustic returns to determine if a shadow belongs to a mine-like object. The mine-like target membership of a shadow depends on the across track and along track dimensions of the shadow, the amount that shadows overlap in adjacent pings, and the along track distance between shadow centers belonging to different acoustic returns. The length and height of the mine is measured and reported to the AUV host. An image of the mine can also be requested by the AUV for transmission via modem to shore or to a support ship. Feasibility of this technology was demonstrated during the FBE workup off Dania , Florida and the FBE off Panama City, Florida when the 850 kHz chirp sidescan, mounted in an OEX AUV, detected all mines in real time.

Dr. Schock and Jim Wulf are the principal engineers developing the sonar technology. They are assisted by 2 technicians and an a graduate and undergraduate students. Jim Wulf is a retired engineer from IBM who designed and tested the electronic components of the sonar processors. Eric Bauer, a graduate student, conducts tank experiments, tested mine detection algorithms, and analyzed the performance of the mine detection system during offshore surveys. Eric graduated with a M.S. in Ocean Engineering in December 2000.

WORK COMPLETED

Over the course of the past year, a preliminary design of modular, compact general purpose sonar for AUV deployment was completed. Low replication cost and low power requirements were driving design criteria. The general purpose sonar module will be used in the chirp sidescan and BOSS(buried object scanning sonar) mine hunting sonars. The module will have a general purpose interface and compact size which allow the sonar to be interfaced to AUVs about the size of Morpheus, Remus, Odyssey AUVs.

RESULTS

The plans for the upcoming year include fabricating and testing low power BOSS and chirp sidescan sonar using the newly developed low power general purpose sonar. BOSS and chirp sidescan sonars will be constructed and tested at sea in a towed mode. The tests will establish the performance of the sonars for detecting buried objects and proud objects in real time. Once testing is completed, the sonars will be deployed on AUVs during follow on technology demonstrations.

IMPACT/APPLICATIONS

The imaging sonars developed under this program can be used for finding mines and ordnance which are buried or lying on the seabed. A buried object imaging sonar, developed by cost sharing between this grant and a CEROS/DARPA contract, can be incorporated into UUVs. Scattering and target strength measurements can be used to predict sonar performance and to aid in the development of other buried object sonars by the Navy. Real time target detection has been implemented in real time in an AUV mounted 850 kHz chirp sidescan which can detect and report mines lying on the seabed.

TRANSITIONS

There were no transition efforts during the past year.

RELATED PROJECTS

None

PUBLICATIONS

"Buried Object Scanning Sonar," Schock et al., IEEE J. of Oceanic Eng., Special Issue on Autonomous Ocean Sampling Networks, Fall 2001 (In Press).

"Results of OEX missions using a chirp sidescan sonar with fuzzy mine detection algorithms," S. G. Schock and E. Bauer, AUV Sensor Workshop, Oceanology International 2001, Miami, April 4, 2001.

"Buried Object Scanning Sonar For UUV Deployment," S. G. Schock, Proceedings, Unmanned Systems 2001, Baltimore, July 31, 2001, p.2393.

"Fuzzy Auto-Detection of Bottom Mines," E. Bauer, Masters of Science Thesis, Florida Atlantic University December 2000.